Design Guide: TIDA-060039

誘導式タッチおよび磁気ダイヤル非接触ユーザー・インターフェイスのリファレンス・デザイン

TEXAS INSTRUMENTS

概要

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Resources

TIDA-060039	Design Folder
SCB	Design Folder
LDC3114-Q1,TMAG5273, DRV2605	Product Folder
TLV755P, TCA9534, PCA9543A	Product Folder

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特長

- シームレスなタッチ面
- 強制タッチ・ボタン
- 磁気ダイヤル
- 押しボタンと回転ダイヤルを 1 つのデバイスで提供
- CORDIC アルゴリズムを内蔵

アプリケーション

- 車載用センター情報ディスプレイ
- 家電製品のユーザー・インターフェイス
- レンジ・フード
- 食器洗い機
- オーブン
- イントルージョン HMI パネル
- ATM (現金自動預け払い機)

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デザイン

English Document: TIDUC26

1 System Description

Human-machine interfaces are a common part of many applications and typically require electro-mechanical components for implementing buttons and dials. Many push buttons use a mechanical switch that has an electrical contact that connects when the button is pressed. This interaction provides a point of wear and tear that can breakdown overtime. Implementing buttons with switches like this also means having to seal the button surface in applications that operate in harsher environments such as industrial or automotive applications. Otherwise, this also allows for dirt or dust to get inside the mechanical button which can further reduce the product lifetime.

Other HMI components like dials also suffer from wear and tear. Dials traditionally use an encoder or potentiometer to determine the rotational change of the input. These components have mechanical components that can breakdown over time similar to push buttons.

In this reference design, inductive sensing is used to implement seamless touch buttons that provide a contact free implementation while also enabling variable force touch functionality. Additionally, hall-effect sensing is used to implement a contactless dial to reduce the wear and tear that comes with devices like potentiometers and rotary encoders. This design includes a 3D-printed housing that provides the button surface and rotational push-button dial.

Since buttons and dials are a common component on many human-machine-interfaces, these technologies can be used in a wide variety of applications. For automotive applications, inductive touch buttons provide a force sensitive response that works with gloves on. Additionally, being able to design with a button on different surfaces provides flexibility to the overall design. These same benefits also apply to other implementations such as industrial HMI and appliances.

2 System Overview

2.1 Block Diagram

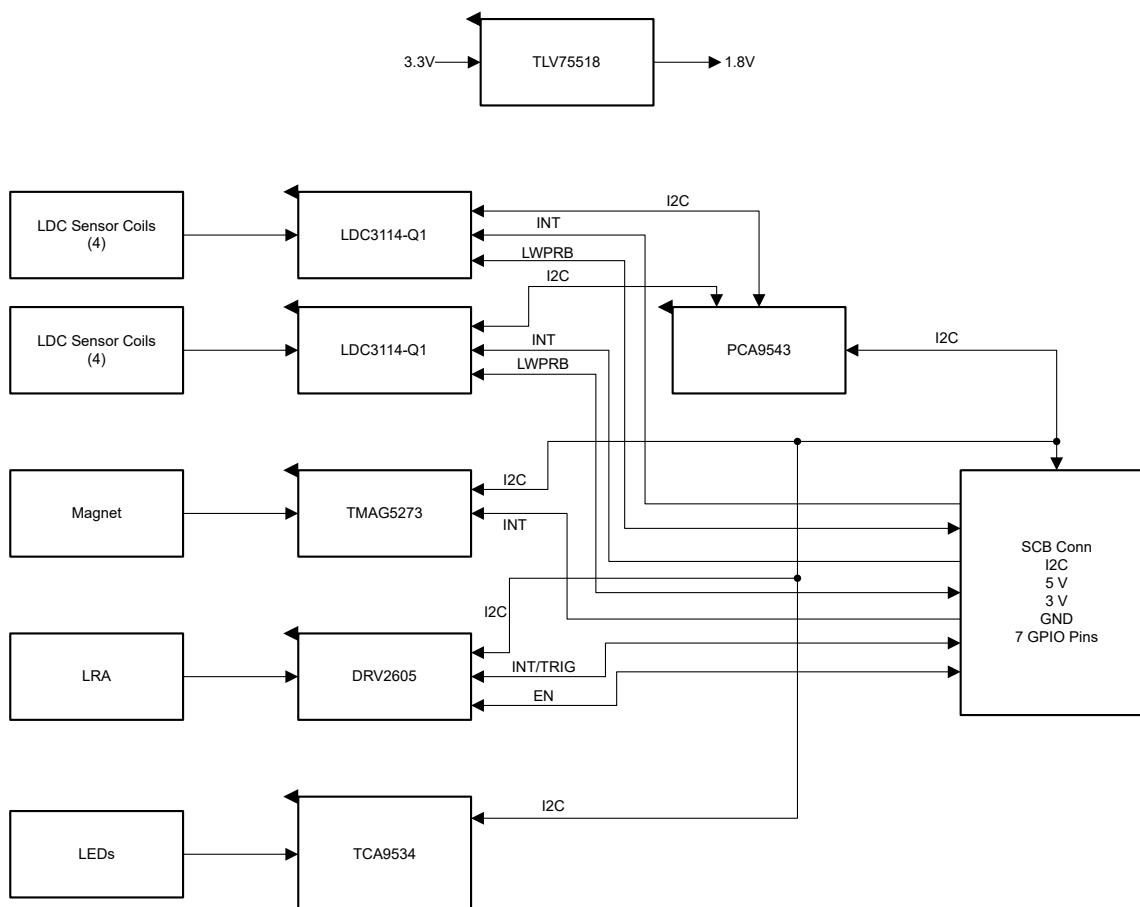The Block Diagram for this reference design is shown in 図 2-1.

図 2-1. TIDA-060039 Block Diagram

The Sensor Control Board (SCB) powers and controls this reference design. The SCB gets power from a USB cable and provides 5 V and 3.3 V to the reference design board. The housing on the reference design provides eight inductive touch buttons and a magnetic push dial. The touch buttons have three different modes of operation that can be changed by pressing in the dial. In the default mode, the buttons will give a digital output on the LEDs corresponding to which button was pressed. In the second mode, the LEDs will showcase how hard any given button is pressed by lighting up more LEDs for a harder press. The third mode connects to a PC and streams data from half of the buttons to a GUI. During all modes of operation, the angle of the magnetic dial is read and displayed on the circular ring of LEDs.

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2.2 Design Considerations

2.2.1 Inductive Touch Buttons

The LDC3114-Q1 is the inductive sensing IC used to implement the touch buttons for this reference design. There are two of these devices implemented on the board, each running four buttons. The LDC3114-Q1 uses an inductive coil to determine the change in a metal target. The force on the metal target creates a deflection in the button case and this deformation is measured by the IC to determine a button press. Additionally, the LDC3114-Q1 includes a baseline tracking algorithm that monitors the button surface and can adapt to environmental factors such as temperature change or damage to the surface. This device also includes digital outputs that trigger when the button data crosses above the given threshold. Since the LDC3114-Q1 does not have a changeable I2C address, an I2C switch (PCA9543) is used to communicate to both devices. This allows for each device to continuously run the baseline algorithm that monitors the button surface.

Implementing an inductive touch button requires a metal target that is at a fixed distance from the sensor coil. Aside form the general design theory for inductive sensors, there are a few important design considerations to keep in mind when designing inductive touch buttons. For some button designs, the desired touch surface might not be metal. In this case, a thin metal plane can be added behind a non-conductive surface, like plastic, that acts as the metal target for the design. The distance between the sensor coil and the metal target is an important factor for getting the desired button sensitivity for an application. The general guideline for this is for the distance to stay between 3-20% of the coil diameter. This ensures that metal target does not touch the sensor coil when it deflects but keeps it close enough to obtain a high force sensitivity. If the metal target gets farther away from the sensor coil, then the button will have decreased sensitivity and can require more force to get a proper button output. Since the target distance is an import part of the design, the coil diameter becomes a critical design parameter as well. Many times, this parameter is constrained by the space available for the sensor coils to be implemented on a PCB. From there, other factors like the number of turns, trace width, trace spacing, and number of layers all account for the overall coil design. The trace width and spacing can be limited by the PCB manufacturing process but can also be useful for changing the series resistance of the inductor coil or allowing for more turns to be included. Generally, it is recommended to use the number of turns to set the inner diameter of the inductive coil between 20-80% since the inner turns do not have as much impact on the magnetic field. However, in a button application, the target is close enough that the inner coils still provide additional benefit so increasing the number of turns to decrease the inner diameter can be considered for the design. For more information on button design, please read the Inductive Touch System Design Guide for HMI Button Applications.

For this reference design, the mechanical structure of the button is comprised of the 3D printed housing, the PCB, and metal tape to provide a target surface. PCB space for the button was not a concern for this design so an 8 mm diameter was chosen for the coil design. The LDC Calculator Tool spreadsheet was used to help determine the rest of the coil parameters. A trace width and spacing of 5 mils was used along with 8 turns per layer. This makes the coil inner diameter slightly smaller than 4 mm. Or in other words, the coil fill ratio (inner diameter divided by outer diameter) is roughly 50%. For most button designs, minimizing the coil fill ratio can provide additional sensitivity but requires the target surface to be very close to the coil for it to be beneficial. Otherwise, it is best to keep the ratio between 20% and 80% to maximize the Q factor of the design. Since this is a two layer board, the number of layers for the coil design was set to two. The capacitance for this sensor design was selected to be 220 pF which put the frequency at 8.396 MHz.
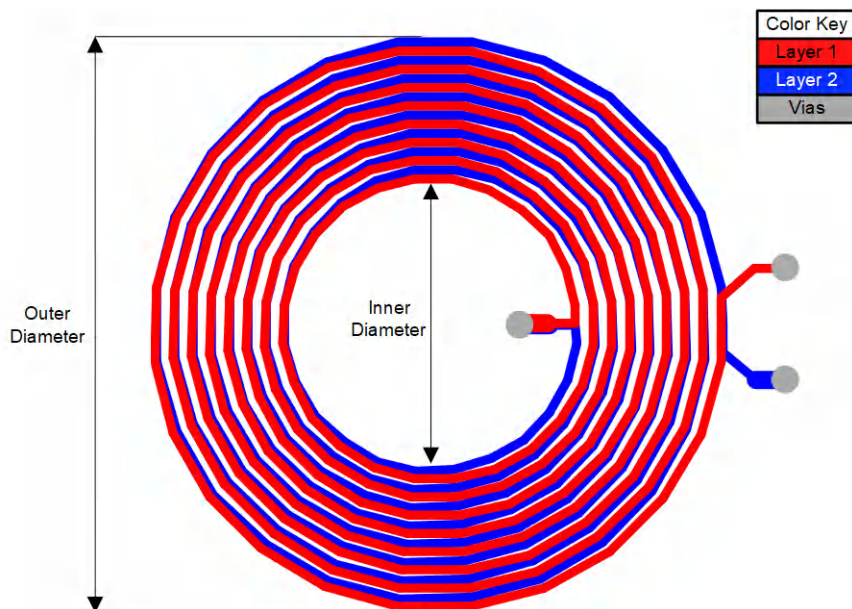
図 2-2. TIDA-060039 LDC Sensor Coil Layout

Based on the coil diameter, the target distance is determined to be 0.8 mm away from the coil. This puts the target well within the recommended 3%-20% range of the coil diameter which will give a high sensitivity in response to a force on the button surface. Going back to the calculator spreadsheet, the target distance can be input to double check the design choices. With the target at 0.8 mm, the sensor frequency is now 11.081 MHz with a Q factor 0f 26. The spreadsheet will give a warning if any of the final parameters are out of range for the device, but in this case, no warnings appear.

表 2-1. LDC Coil Calculator Outputs

Description	Designator	Value	Unit
Total Inductance with no target	L_{TOTAL}	1.604	µH
Sensor Operating Frequency no target	f_{RES}	8.396	MHz
R_P with no Target	R_P	3.19	kΩ
Q factor	Q	37.00	
Self resonant frequency (estimated)	SRF	62.831	MHz
Target Distance	D	0.800	mm
Sensor Inductance from Target Interaction	L'	0.921	µH
Sensor Frequency with Target Interaction	f_{RES}'	11.081	MHz
R_P with Target Interaction	R_P'	1.68	kΩ
Q Factor with target	Q'	26.0	

Since the button surface is 3D printed, it also includes the required spacer for the button design instead of having a separate spacer material. The standoff and button surfaces are both 1 mm thick to provide a surface that has some slight flexibility and to set our target height as desired. The metal tape is then placed inside the button surface between the standoffs so that it deflects in the desired area when a force is applied to the button surface. The thickness of the tape then puts the target at about 0.8 mm away from the sensor coil.
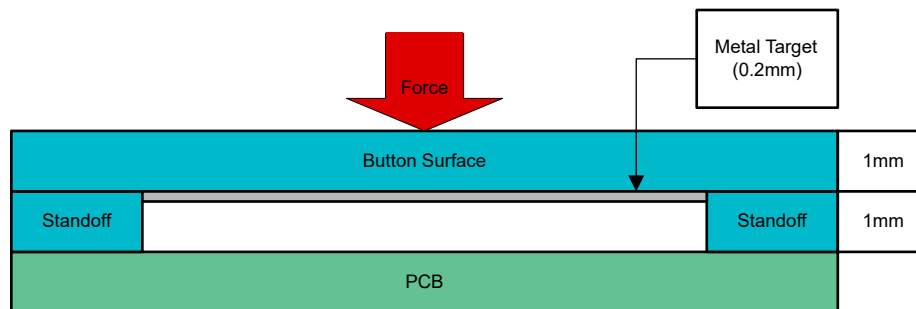
図 2-3. Inductive Touch Button Stackup

The material of the button surface has an impact on how much deflection will occur to the metal target. Materials that are more stiff or that absorb the force will cause less deflection and therefore will require more force for a button press to be detected. This also comes into play when considering the thickness of the button surface. The LDC Calculator Tool Spreadsheet has a tab for determining the deflection of a material if the Young's Modulus and Poisson Ratio are known for the material. Since this design is 3D printed using nylon 12, a deflection of around 20 µm is expected for a 2N force applied to the surface. This amount of deflection will be plenty for this button design since the target is so close to the sensor to begin with.

Using metal tape or a small metal target on the inside of the button surface allows for non-metal materials to work in a button fabrication. Performance will vary depending on the metal used for the target. It is desired to use a metal with a high conductivity to maximize the sensitivity of the button. Because of this, both copper and aluminum tape are strong options since they have a high conductivity and can easily be cut to fit within the spacers for the button design. An alternative approach to this is having a metal layer attach to the button surface and placing the spacers between the metal layer and PCB sensors such as in the 図 2-4. See the Inductive Touch System Design Guide for HMI Button Applications application note for more information on button design.
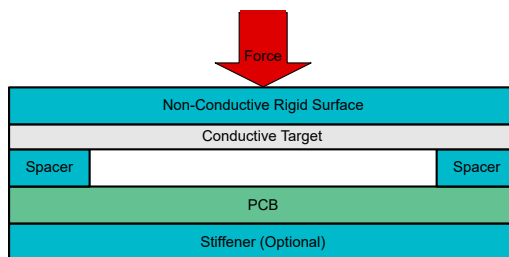

図 2-4. Non-Conductive Touch Button Alternative Stackup Example

2.2.2 Sensor Coil Placement

The LDC3114 allows for sensor coils to be placed remotely rather than next to the IC due to the addition of the COM pin and placing the sensor capacitor near the device instead of next to the coil. This provides a better EMI response for the coil and eliminates the need for additional filtering in most cases. Due to the sensor coils being placed at different distances from the IC, their trace lengths vary and cause a slightly different series resistance value for each coil. This can also lead to a slightly different resonant frequency of the different sensors but since the button application uses the baseline tracking algorithm, it does not need to have an exact measurement on each channel and cares more about the change in the data than what the data value starts at.

2.2.3 Collecting Data from Multiple LDCs

Since the LDC3114 uses the same I2C address, an I2C mux is used to communicate with each device independently. Each LDC3114 is driving four sensor coils at the default 40SPS. Since touch buttons do not require high-speed operation, the sample rate does not need to be increased and polling each device for their data does not cause a latency issue on the touch button. For battery powered applications, the sample rate can be decreased and the digital outputs of the LDC3114 can be monitored instead of using the I2C data. In this design, there were limited GPIO ports on the connector to the main controller so the digital outputs are read from the OUT register of each device instead.

2.2.4 Magnetic Dial Implementation

The TMAG5273 is a 3D hall-effect sensor used to implement the dial in this design. Being a 3D device allows it to detect the angle and magnitude of the magnet which enables the push-button functionality on the dial. The integrated CORDIC engine of this device makes angular position sensing easy to implement in this application. The angle of magnet is reported through the device register so no calculations are needed from the MCU. Another device that can be used for this application is the TMAG5170-Q1, an automotive qualified part that provides similar functionality. It also has the built in CORDIC engine and reports the magnet angle and magnitude through the registers. The two parts are slightly different in that the TMAG5170-Q1 is a high precision device that uses SPI for communication while the TMAG5273 is low power and uses I2C. This reference design does not need high resolution to display the angle and has I2C as the main communication protocol so the TMAG5273 was chosen. If automotive qualification is needed, the TMAG5170-Q1 would be used instead.

The magnet used in this device is an N42 diametric cylinder measuring 1/4th in diameter by 1/8th inch thick. This magnet was chosen because it provides an input that uses a significant portion of the full-scale output range. This provides a better SNR performance for the device when used at a suitable distance for the design while still being small and it is easy to obtain.
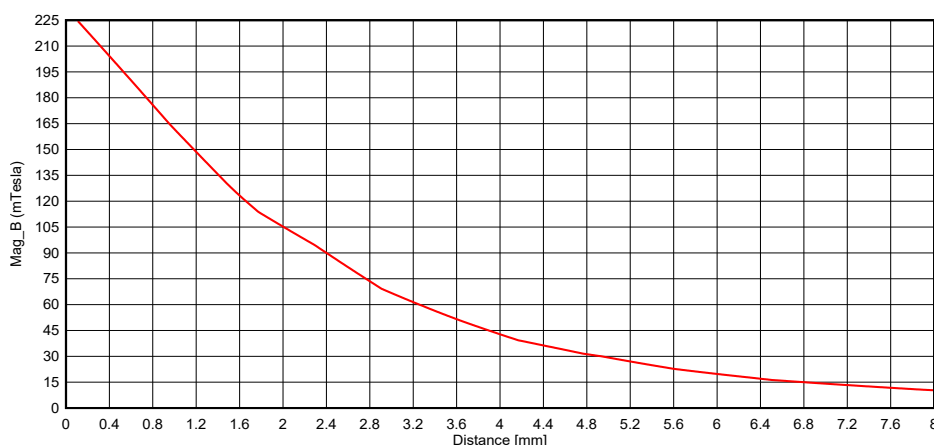

図 2-5. Magnetic Field Strength Over Distance

The push functionality of the dial is achieved by adding a spring to the design. Most springs are ferromagnetic and will interact with the magnetic field but the magnet chosen for this design has a field strong enough that the spring can still be implemented without needing to find a specific non-ferromagnetic version. However, the decrease in field strength also reduces the SNR for this design. This is combated by implementing averaging in the magnetic measurement. The TMAG5273 has a register setting that can be used to change the averaging of the sensor data. Since high speed measurements are not needed in this application, the maximum averaging is chosen for consistent results. Alternatively, the averaging can be turned down to the necessary value and the sleep timer in the device can be used to put the device in low-power mode between samples for lower power applications.
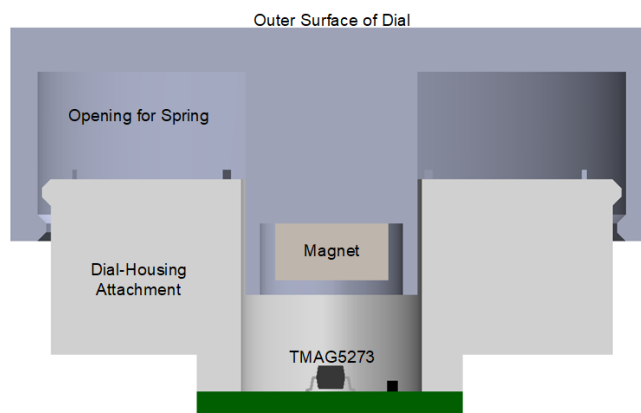
図 **2-6. Magnetic Dial Push Button Stackup**

Knowing the distance between the magnet and the sensor as well as the magnet properties, the angle error can be estimated using the Angle Error Calculation Tool. However, since this application does not require a fast sampling rate, the CORDIC algorithm with a high sample averaging applied will give accurate enough information about the dial's position.

2.2.5 CORDIC Algorithm

The built in CORDIC algorithm uses two magnetic axes to determine the angle data. The linear magnetic axis data can also be used to calculate the angle using an external algorithm as well. For using the internal CORDIC algorithm, the desired magnetic axis need to be selected using the ANGLE_EN bits in the SENSOR_CONFIG_2 register in the device. For this design, the X and Y axis are used to determine the magnet angle so the bits are set to 0x1. In addition to this, it is important to set the magnetic sensing range based on the expected magnetic field strength. Once configured, the magnet angle can be obtained from the CORDIC algorithm by simply reading the ANGLE_RESULT_MSB and ANGLE_RESULT_LSB registers. Lastly, averaging is applied to the sampling of the device by changing the CONV_AVG register setting. This allows for a better SNR performance from the device and gives more accurate angle information from the CORDIC output.

2.3 Highlighted Products

2.3.1 LDC3114-Q1

The LDC3114-Q1 is an inductive sensing device that enables touch button design for human machine interface (HMI) on a wide variety of materials by measuring small deflections of conductive targets using a coil that can be implemented on a small printed circuit board (PCB) located behind the panel. This technology can be used for precise linear position sensing of metal targets for automotive, consumer and industrial applications by allowing access to the raw data representing the inductance value. Inductive sensing solution is insensitive to humidity or non-conductive contaminants such as oil and dirt.

The button mode of LDC3114-Q1 is able to automatically correct for any deformation in the conductive targets. The LDC3114-Q1 offers well-matched channels, which allow for differential and radiometric measurements which enable compensation of environmental and aging conditions such as temperature and mechanical drift. The LDC3114-Q1 includes an ultra-low power mode intended for power on/off buttons or position sensors in battery powered applications.

2.3.2 TMAG5273

The TMAG5273 is a low-power linear 3D Hall-effect sensor designed for a wide range of industrial and personal electronics applications. This device integrates three independent Hall-effect sensors in the X, Y, and Z axes. A precision analog signal chain along with an integrated 12-bit ADC digitizes the measured analog magnetic field values. The I 2C interface, while supporting multiple operating VCC ranges, ensures seamless data communication with low-voltage microcontrollers. The device has an integrated temperature sensor available for multiple system functions, such as thermal budget check or temperature compensation calculation for a given magnetic field.

The TMAG5273 can be configured through the I2C interface to enable any combination of magnetic axes and temperature measurements. Additionally, the device can be configured to various power options (including wake-up and sleep mode) allowing designers to optimize system power consumption based on their system-level needs. Multiple sensor conversion schemes and I2C read frames help optimize throughput and accuracy. A dedicated INT pin can act as a system interrupt during low power wake-up and sleep mode, and can also be used by a microcontroller to trigger a new sensor conversion.

An integrated angle calculation engine (CORDIC) provides full 360° angular position information for both on-axis and off-axis angle measurement topologies. The angle calculation is performed using two user-selected magnetic axes. The device features magnetic gain and offset correction to mitigate the impact of system mechanical error sources

2.3.3 DRV2605

The DRV2605 device is designed to provide extremely-flexible haptic control of ERM and LRA actuators over a shared I 2C-compatible bus. This control relieves the host processor from ever generating pulse-width modulated (PWM) drive signals, saving both costly timer interrupts and hardware pins. The DRV2605 device provides an extensive integrated library over 100 licensed effects from Immersion for ERM and LRA which eliminates the need to design haptics waveforms. The DRV2605 device offers a licensed version of the TouchSense 2200 software from Immersion, which includes the 2200 Effects Library, and 2200 audio-to-vibe features. Additionally, the real-time playback mode allows the host processor to bypass the library playback engine and play waveforms directly from the host through I2C. The DRV2605 device also contains a smart-loop architecture, which allows effortless auto resonant drive for LRA as well as feedback-optimized ERM drive. This feedback provides automatic overdrive and braking, which creates a simplified input waveform paradigm as well as reliable motor control and consistent motor performance. This feature is utilized to control an LRA in this reference design.

2.3.4 TLV75518

The TLV755P is an ultra-small, low quiescent current, low-dropout regulator (LDO) that sources 500 mA with good line and load transient performance. The TLV755P is optimized for a wide variety of applications by supporting an input voltage range from 1.45 V to 5.5 V. To minimize cost and solution size, the device is offered in fixed output voltages ranging from 0.6 V to 5 V to support the lower core voltages of modern microcontrollers (MCUs). Additionally, the TLV755P has a low IQ with enable functionality to minimize standby power. This device features an internal soft-start to lower inrush current, thus providing a controlled voltage to the load and minimizing the input voltage drop during start up. When shutdown, the device actively pulls down the output to quickly discharge the outputs and ensure a known start-up state.

This reference design uses the 1.8 V output option of this device to supply power to the LDC3114 devices and level shifters.

2.3.5 TCA9534

The TCA9534 is a 16-pin device that provides 8 bits of general purpose parallel input and output (I/O) expansion for the two-line bidirectional I 2C bus (or SMBus) protocol. The device can operate with a power supply voltage ranging from 1.65 V to 5.5 V, which allows for use with a wide range of devices. The device supports both 100-kHz (Standard-mode) and 400-kHz (Fast-mode) clock frequencies. I/O expanders such as the TCA9534 provide a simple solution when additional I/Os are needed for switches, sensors, push-buttons, LEDs, fans, and other similar devices. In this reference design, multiple of these devices are used to control the LEDs on the board.

2.3.6 PCA9543

The PCA9543A is a dual bidirectional translating switch controlled by the I2C bus. The SCL/SDA upstream pair fans out to two downstream pairs, or channels. Either individual SCn/SDn channel or both channels can be selected, determined by the contents of the programmable control register. Two interrupt inputs (INT1– INT0), one for each of the downstream pairs, are provided. One interrupt output (INT) acts as an AND of the two interrupt inputs. An active-low reset (RESET) input allows the PCA9543A to recover from a situation where one of the downstream I2C buses is stuck in a low state. Pulling RESET low resets the I2C state machine and causes both of the channels to be deselected, as does the internal power-on reset function. This device is used in this reference design to allow communication to both LDC3114-Q1 devices since they share the same I2C address.

2.3.7 Sensor Control Board

The sensor control board (SCB) is the MCU board that controls the reference design using an MSP432. This board handles the firmware and USB interface for the design. The SCB can easily be detached and used with different EVMs that are supported by it. For more information on the SCB, please visit the TI Sensor Control Board (SCB) for Evaluation Modules website.

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3 Hardware, Software, Testing Requirements, and Test Results

3.1 Firmware and Programming

This reference design uses the SCB to control the different ICs on board. The firmware for this design was developed using Code Composer Studio. Once the SCB is flashed with the proper firmware, it can be used along with this reference design. Since the SCB can be used with multiple EVMs, it can easily be flashed by using the GUI to upload the proper firmware.
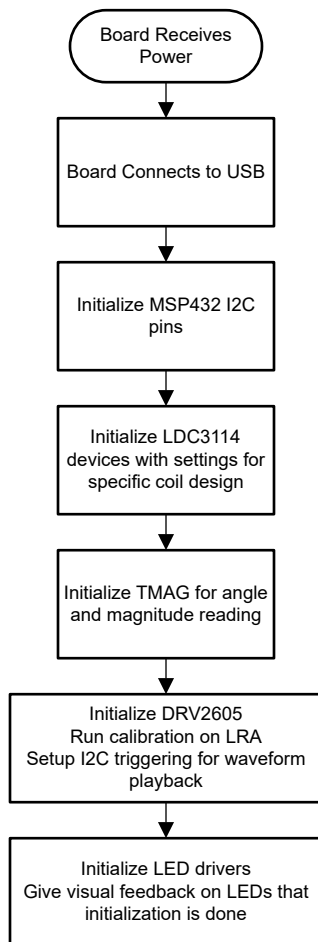
図 3-1. Initialization Flowchart

The firmware for this design starts by initializing the different ICs on the board. The LDC3114s are setup for the button application and set the registers according to the coil design discussed above. The DRV2605 haptic driver is setup to perform haptic feedback when and I2C command is received. The device is also setup for the specific LRA that is attached to the board and runs a calibration check each initialization. The TMAG5273 is setup so that the X and Y components of the magnetic field are used for rotational calculations. This device can also be configured to send interrupts under specific conditions, but that is not used in this design. Additionally, each mode in this design uses the angle from the TMAG5273 to determine which LED to turn on for the dial position. Since this is acting like a 12-position selector, hysterisis is added to the dial angle output. This prevents cases where the angle could be right on the line between two LED outputs causing the two LEDs to flicker back and forth. This has the same impact as included a physical keep out method for the position between each of the 12 LEDs.
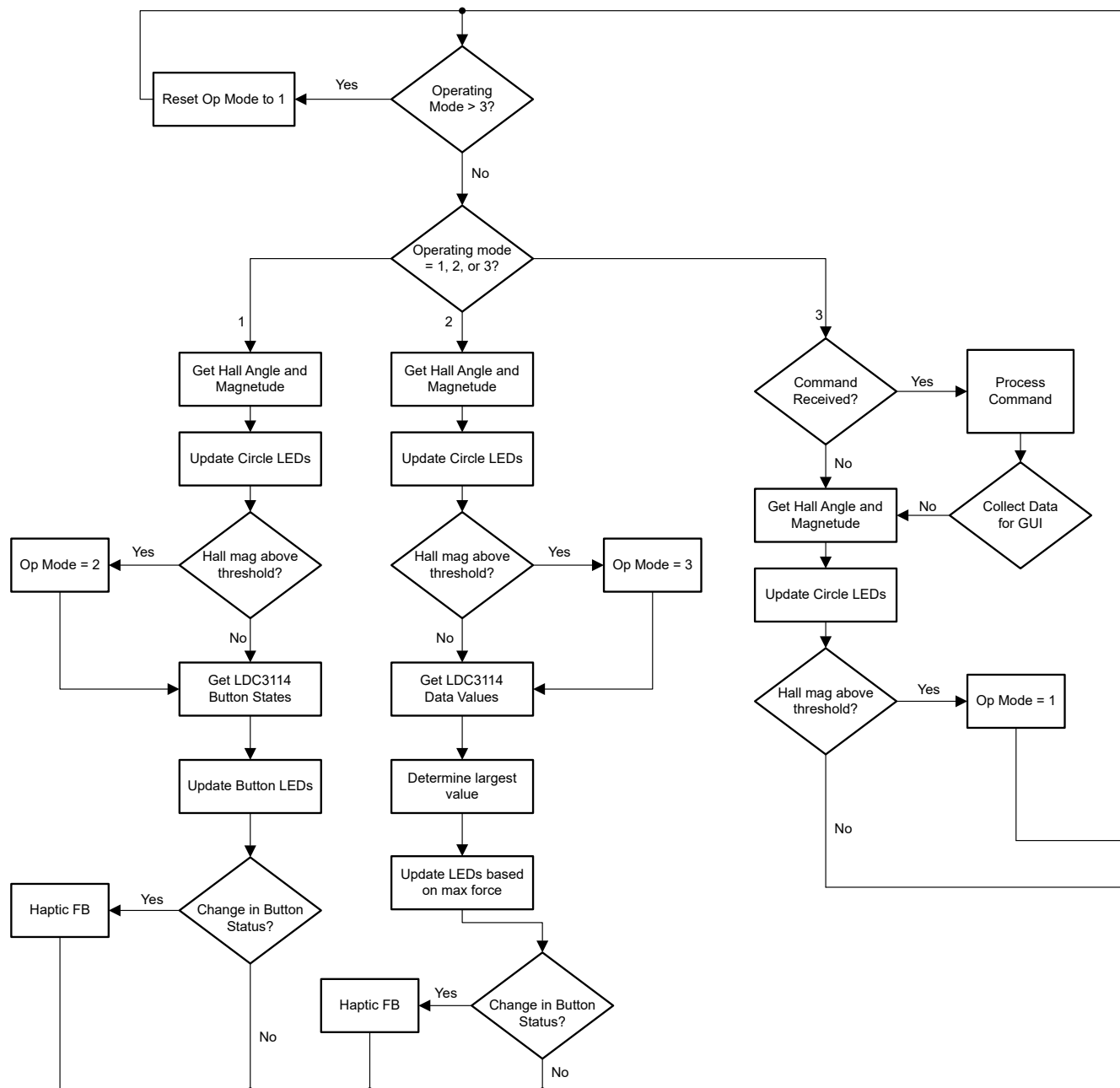
図 3-2. Operational Modes Flowchart

During normal operation, this reference design has three different operational modes that change the functions of the inductive touch buttons.

Operational Mode 1

The reference design defaults into operational mode 1 on startup. This mode uses the LDC3114's baseline tracking algorithm to implement eight different touch buttons. When each of these buttons are pressed, the digital output of the LDC3114s are monitored and correlate to an LED on the board. The digital outputs of the LDC3114 trigger when the baseline algorithm data gets higher than the button threshold. Once this happens, the pins on the device and the OUT register both show the button status as high depending on the polarity setting of the device. The LEDs used to show the button feed back will only light up one LED from a button press on each side of the board. This is because the MAXWIN feature of the LDC3114 is enables to prevent cases where two buttons on the same side can be pressed by putting hard enough on one button that the next button also triggers. Since this is applied by the LDC3114, a button press from each device can show on the LEDs at the same time. For more information on the LDC3114's internal algorithm, see the LDC211x and LDC3114 Internal Algorithm Functionality application note. When in mode 1, a press to the magnetic dial button puts the operational mode into mode 2.

Operational Mode 2

The second operational mode of this reference design is very similar to the first one. The LDC3114s are still setup in baseline tracking mode but the way the LEDs report is different. This mode looks at the data value from the baseline tracking algorithm on all buttons and determines which button has the highest force press. From there, LEDs are lit up depending on how hard the button is pressed with more force turning on more LEDs. Each time this mode is entered, a max force is reset to a standard value. If a button is pressed hard enough, a new maximum force value will be saved to compare against other button presses. For example, if the starting maximum is 200, a data value of 100 will light up the first four LEDs. If the button algorithm reports a result of 400, the new maximum value will be set to 400 while lighting up all the LEDs. Then, the next time the data value reads 100, only two of the LEDs will light up. The magnetic dial push button will change the operational mode to mode 3 when pushed.

Operational Mode 3

Operational mode 3 of this reference design disables the button algorithm in one of the LDC3114s and gives access to the raw data response for the buttons. The button LEDs go into a fixed state to showcase that operational mode 3 is active. The firmware waits for a command from the GUI to collect data. Once a streaming command has been received, the firmware will stream raw data results from all four channels from the LDC to the GUI. This can be used to take data on the graph similar to the way BOOST-LDC3114EVM works in raw data mode.

3.2 Test Setup

The buttons on this reference design were designed with the same parameters but due to mechanical tolerances there can be slight differences in performance. Since the design is meant to be 3D printed, different printers or printing technologies will have different accuracies and tolerances. Additionally, if a different material is used for the 3D printing, then deflection of the button surface will change and can require more force for a press event to trigger a button output. Even though the buttons on a single print will all have the same printer and material, there can still be variation in force required for a button, especially if the design is hand assembled. The tape used to keep the mechanical tolerance can have an impact on the button if it is not uniform or differs between units. To showcase this, an analog force gauge is used to apply a force to the button surface. The force required for each button threshold to trigger is then recorded as well as the raw data response for varying forces. Additionally, testing is performed on two different material types with different 3D printing processes while keeping the same mechanical design.

3.3 Test Results

The required force for each button press shows the difference in mechanical structure that can occur when using materials that are not completely uniform or have design tolerances large enough to impact the performance. Additionally, testing with two different materials shows the differences between them as well.

表 3-1. Button Press Force Required

Button Position	ABS Left (Newtons)	ABS Right (Newtons)	Nylon Left (Newtons)	Nylon Right (Newtons)
1	7	5	2	3.75
2	20	3.5	3	0.75
3	16	1.5	1	1.5
4	3	1	3	1

3.3.1 ABS Force Response

The differences shown between the buttons is due to more than just the material difference. Because these test units were hand assembled, there is variation in the mechanical alignment and the adhesion that creates the mechanical isolation. This difference can cause some of the buttons to have a worse response and can be alleviated by having a controlled and repeatable assembly process. The different force responses can be offset by applying a different gain factor to each button so they all end with a button output at the same force. To better showcase this, the raw data is collected for each button with varying forces. The force response for the ABS button surface is shown in 図 3-3.

(a) Left Side

(b) Right Side
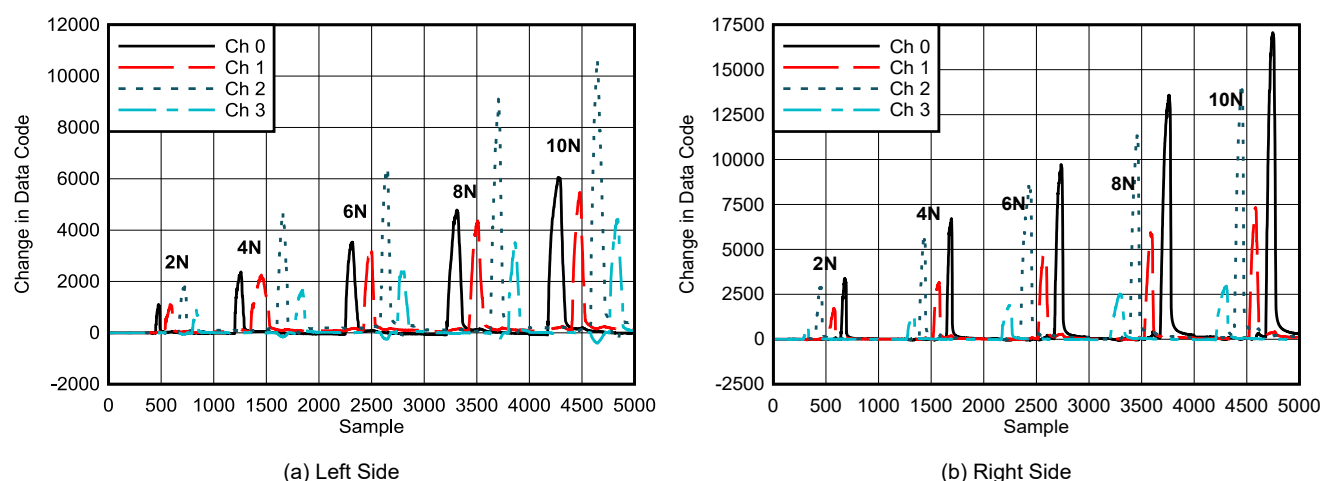
図 3-3. ABS Force Response

3.3.2 ABS Gain Corrected

The ABS force response shows the different sensitivities of the buttons. Even though they were designed the same, the mechanical function is different in each case due to variance in the 3D printing. To achieve a more even response, a gain can be applied to each channel. After applying individual gains, the force response can be seen in 図 3-4.
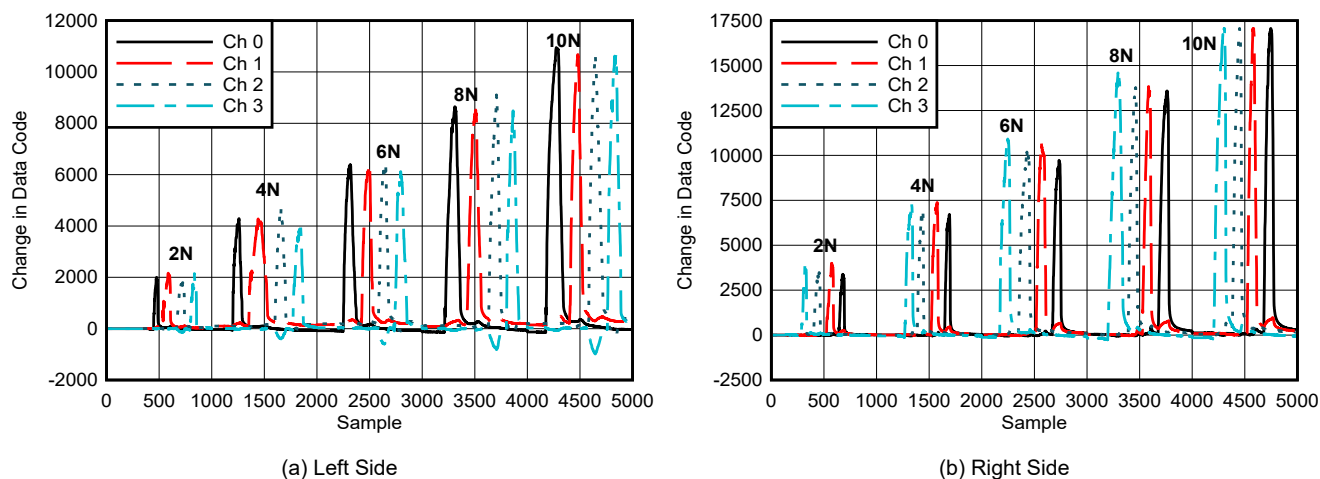

(a) Left Side

(b) Right Side

図 3-4. ABS Gain Corrected

3.3.3 Nylon Force Response

Similarly, the Nylon 12 force response is gathered and compared.

表 3-2.

(a) Left Side

(b) Right Side
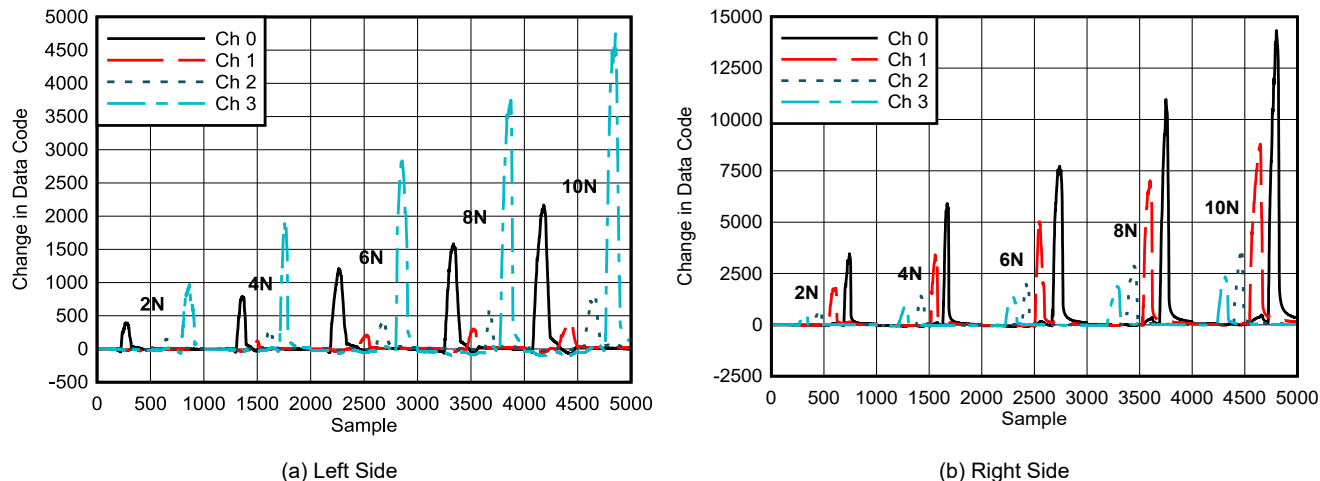
図 3-5. Nylon Force Response

3.3.4 Nylon Gain Corrected

The Nylon had a wider range in button forces required so the gain correction requires larger values than the ABS to obtain an even response.

(a) Left Side

(b) Right Side
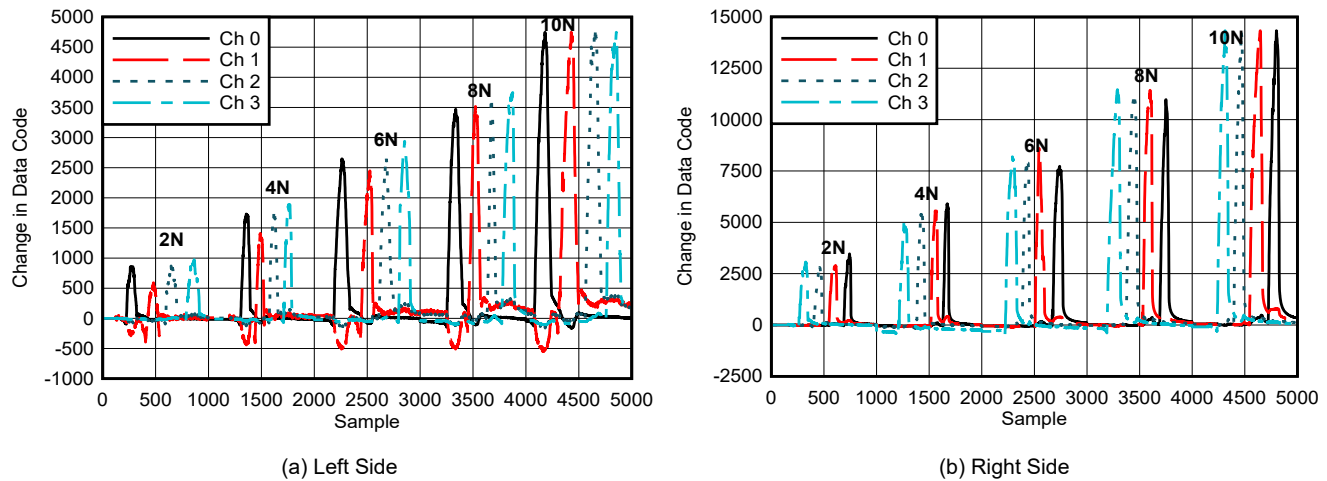
図 3-6. Nylon Gain Corrected

The downside to having the increased gain correction is the inverse response that can be seen on some button channels while other nearby buttons are pressed. This occurs due to the mechanical nature of the button design where the press on one button causes the other button surface to slightly flex away from the sensor coil. Since the data moves in the opposite direction from the button press, the impact can be ignored in the application and the baseline algorithm in the device has additional tools to handle this impact so that it does not become an issue. That being said, cases like this can be minimized by isolating the mechanical movement as best as possible.

Lastly, after gain correction on both materials, the difference between the two can be seen. From the graphs, the ABS has a larger response to each force applied than the Nylon. This is partially be due to the difference of materials but also due to the assembly of the housing. The adhesion between the PCB and button surface is done by hand on the test units and can lead to imperfections in the design. This shows the importance of having a tight assembly process to obtain consistent results between units.

4 Hardware Components

The 3D printed housing is separated into different components and assembled into the final housing. These components were designed for a Selective Laser Sintering process that uses Nylon 12 as the material. This gives the button surface slight flexibility to bend and allows for the magnetic dial to rotate smoothly. The design starts with a housing base that provides a rigid surface for the PCB to sit in as well as a hole for the USB cable and multiple holes for the bolts to secure the housing shut.
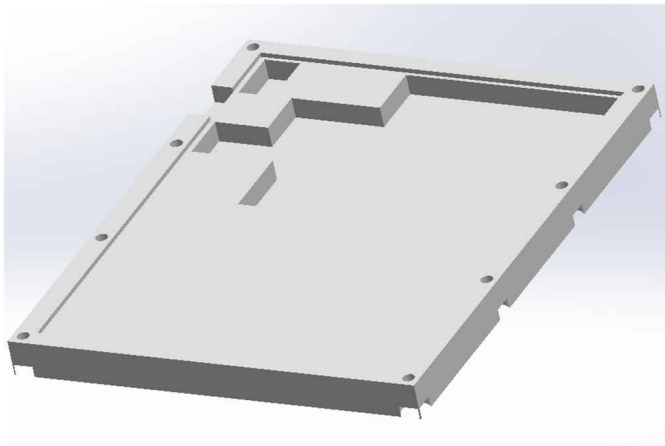
図 4-1. Housing Base

The PCB rests inside the groove around the outside of the base along with the SCB attached.
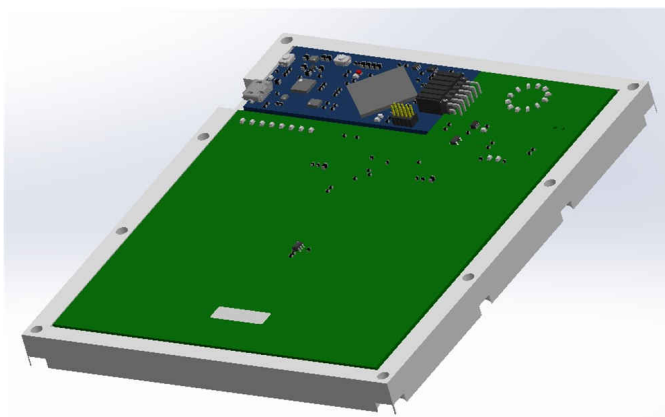
図 4-2. Housing Base with PCB

The top cover is broken into multiple parts to make it easier to print with some 3D printing technologies. These different parts are the button surface, a dial attachment, the dial, and a small cover for the top portion of the PCB. The button surface has grooves on the top to show where a button press should occur and a hole in the middle for the dial attachment piece to sit in. On the back, there are rectangular cutouts for the metal targets to be added into. To obtain the best mechanical isolation, the button cover is adhered to the PCB as well as bolted to the housing base. This portion of the design was built to match the button stackup design previously mentioned.
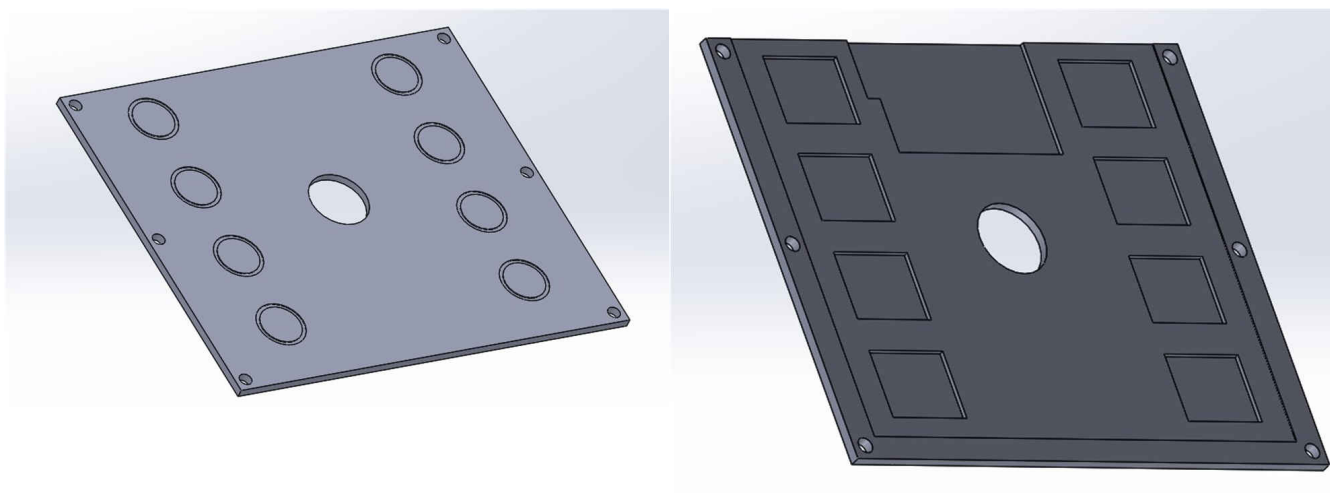
図 4-3. Housing Button Cover

The dial attachment is a small round piece that sits in the hole of the button surface. The main purpose is to provide a spot for the dial to clip into. The dial attachment needs to be fixed to the button surface with glue to ensure that it does not move when using the button.
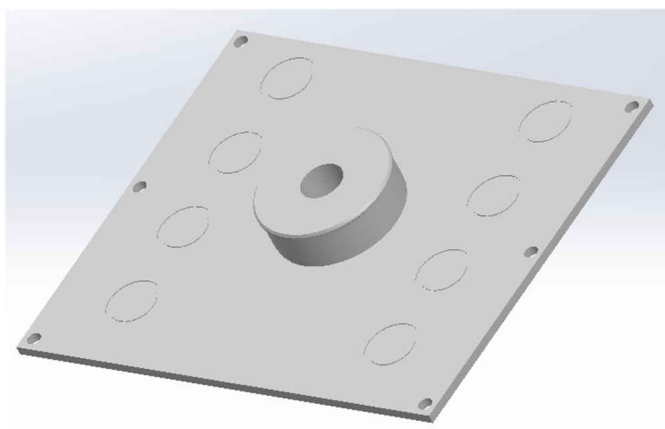

図 4-4. Button Cover with Dial Attachment

The dial is designed to clip onto the dial attachment with a spring sitting between the two. The dial also has a small hole that the magnet gets glued into. This allows for the magnet to sit directly above the TMAG5273 for best rotational sensing measurements.
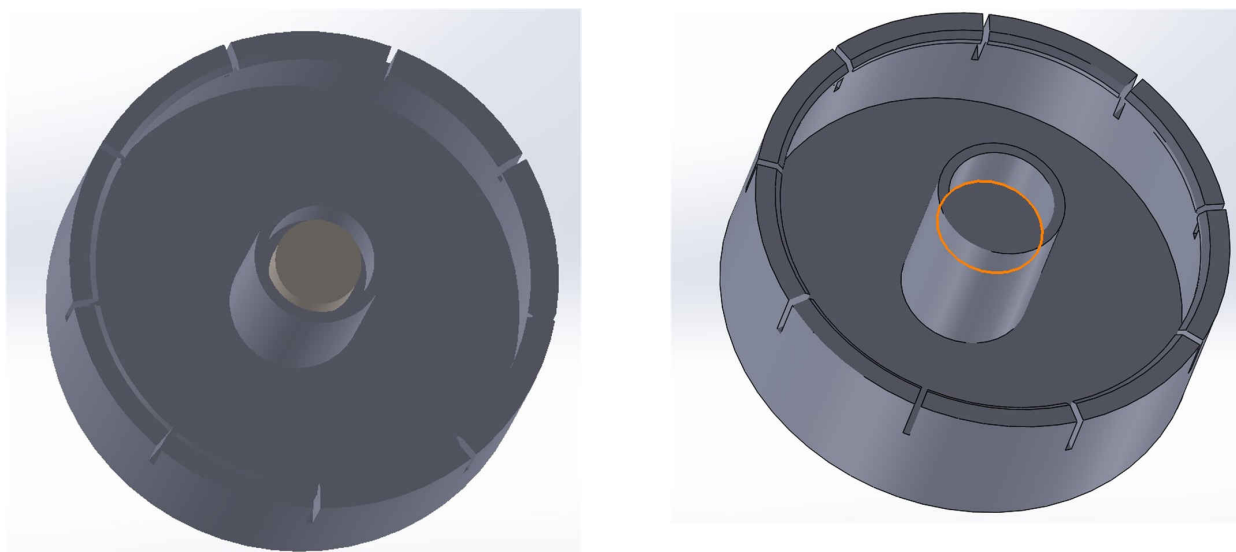
図 4-5. Magnetic Dial

The small top cover has some cutouts to let the LEDs be visible even when the cover is on as well as a cutout for the USB cable to connect to the SCB. The main purpose of the top cover is to complete the housing and hold the SCB in place.
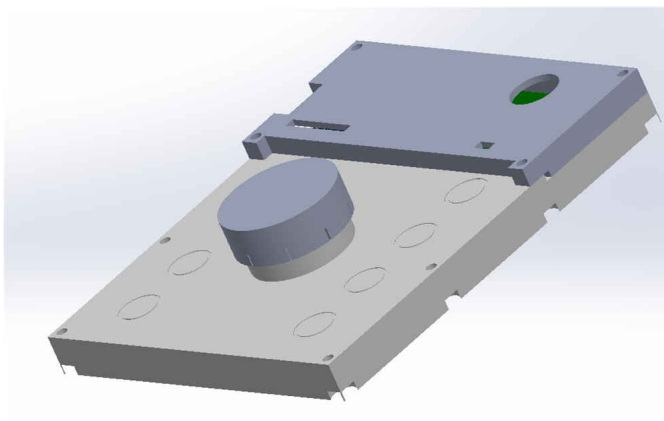
図 4-6. Full Assembly

5 Design and Documentation Support
5.1 Design Files

5.1.1 Schematics

To download the schematics, see the design files at TIDA-060039.

5.1.2 BOM

To download the bill of materials (BOM), see the design files at TIDA-060039.

5.2 Tools and Software

Tools

Inductive Sensing Design Calculator Excel spreadsheet to help inductive coil sensor design

Angle Error Calculator Magnetic sensor angle error calculator for the TMAG5170 and TMAG5273

5.3 Documentation Support

1. Texas Instruments, Inductive Touch System Design Guide for HMI Button Applications application note.
2. Texas Instruments, Inductive Touch Buttons for HMIs application brief.
3. Texas Instruments, LDC211x and LDC3114 Internal Algorithm Functionality application note.
4. Texas Instruments, Inductive Touch – Configuring LDC2114 and LDC3114 Touch-Button Sensitivity application report.

5.4 サポート・リソース

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